Chapter 10

**Agricultural Waste Management System
Component Design**

Part 651
Agricultural Waste Management
Field Handbook

651.1050   Appendix 10A—Blank worksheets

Worksheet 10A-1—Waste storage structure capacity design

Decisionmaker:	Date:

Site:

Animal units

1. Animal type _____ _____ _____

2. Animal weight, lbs (W) _____ _____ _____

3. Number of animals (N) _____ _____ _____ _____

4. Animal units, $AU = \dfrac{W \times N}{1000}$ = _____ _____ _____ _____

Manure volume

5. Daily volume of daily manure production
   per AU, ft^3/AU/day (DVM)= _____ _____ _____

6. Storage period, days (D) = _____ _____

7. Total volume of manure production for
   animal type for storage period, ft^3
   VMD = AU x DVM x D   = _____ _____ _____

8. Total manure production for storage period, ft^3 (TVM) _____ _____

Wastewater volume

9. Daily wastewater volume per
   AU, ft^3/AU/day (DWW) = _____ _____ _____

10. Total wastewater volume for animal
    description for storage period, ft^3
    WWD = DWW x AU x D = _____ _____ _____

11. Total wastewater volume for
    storage period, ft^3 (TWW) _____ _____

Bedding volume

12. Amount of bedding used daily
    for animal type,
    lbs/AU/day (WB) = _____ _____ _____

13. Bedding unit weight,
    lbs/fb^3 (BUW) = _____ _____

14. Bedding volume for animal type
    for storage period, ft^3 BV =   _____ _____ _____

$$VBD = \frac{0.5 \times WB \times AU \times D}{BUW}$$

15. Total bedding volume for storage
    period, ft^3 (TBV) = _____ _____

Minimum waste storage volume requirement

16. Waste storage volume, ft^3 (WV) = TVM + TWW + TBV = _____ + _____ + _____ = _____

Waste stacking structure sizing

17. Structure length, ft $L = \dfrac{WV}{WI \times H}$ = _____

18. Structure width, ft $WI = \dfrac{WV}{L \times H}$ = _____

19. Structure height, ft $H = \dfrac{WV}{L \times WI}$ = _____ _____

Notes for waste stacking structure:

1. The volume determined (WV) does not include any volume for freeboard. It is recommended that a minimum of 1 foot of freeboard be provided for a waste stacking structure.

2. The equations for L, WI, and H assume manure is stacked to average height equal to the sidewall height. Available storage volume must be adjusted to account for these types of variations.

Tank sizing

20. Effective depth, ft. (EH)

   Total height (or depth) of tank desired, ft (H) _____

      Less precipitation for storage period, ft. _____ – _____
      (uncovered tanks only)

      Less depth allowance for accumulated solids, ft – _____
      (0.5 ft. minimum)

      Less depth for freeboard (0.5 ft. recommended), ft – _____

      Effective depth, ft (EH) = _____ _____

21. Surface area required, ft^2 $SA = \dfrac{WV}{EH}$ = _____

22. Rectangular tank dimensions

   Total height, ft (H) = _____ Selected width, ft (WI) = _____

   Length, ft $L = \dfrac{SA}{WI}$ = _____

23. Circular tank dimensions

   Total height, ft   H   = _____

   Diameter, ft   DIA = (1.273 x SA)$^{0.5}$ = _____

Notes for waste storage tank structure:
1. Final dimensions may be rounded up to whole numbers or to use increments on standard drawings.
2. Trial and error may be required to establish appropriate dimensions.

Worksheet 10A-2—Waste storage pond design

Decisionmaker:	Date:

Site:

Animal units

1. Animal type _____ _____ _____ _____

2. Animal weight, lbs (W) _____ _____ _____

3. Number of animals (N) _____ _____ _____ _____

4. Animal units, $AU = \dfrac{W \times N}{1000}$ = _____ _____ _____ _____

Manure volume

5. Daily volume of manure production
   per AU, ft^3/AU/day (DVM) = _____ _____ _____

6. Storage period, days (D) = _____ _____

7. Total volume of manure production for
   animal type for storage period, ft^3 _____ _____ _____
   VMD = AU x DVM x D   =

8. Total manure production for storage period, ft^3 (TVM) _____ _____

Wastewater volume

9. Daily wastewater volume per
   AU, ft^3/AU/day (DWW) = _____ _____ _____

10. Total wastewater volume for animal
    description for storage period, ft^3
    WWD = DWW x AU x D = _____ _____ _____

11. Total wastewater volume for
    storage period, ft^3 (TWW) _____ _____

Clean water volume

12. Clean water added during storage period, ft^3 (CW) _____

Solids accumulation

14. Volume of solids accumulation, ft^3 (VSA) _____ _____

Runoff volume

13. Runoff volume, ft^3 (ROV) (attach documentation) _____ _____
    Includes the volume of runoff from the drainage area
    due to normal runoff for the storage period and the
    runoff volume from the 25-year, 24-hour storm.

Minimum waste storage volume requirement

15. Waste storage volume, ft^3 (WSV) = TVM + TWW + CW + ROV + VSA

    = _____ + _____ + _____ + _____ + _____ = _____

Pond sizing

16. Sizing by trial and error

Side slope ratio, (Z) = _____   V must be equal to or greater than WSV = _____ ft^3

Rectangular pond,

$$V = \left(\dfrac{4 \times Z^2 \times d^3}{3}\right) + \left(Z \times BL \times d^2\right) + \left(Z \times BW \times d^2\right) + \left(BW \times BL \times d\right)$$

Circular pond,

$$V = (1.05 \times Z^2 \times d^3) + (1.57 \times W \times Z \times d^2) + (0.79 \times W^2 \times d)$$

Trial no.	Bottom width ft (BW)	Bottom length ft (BL)	Depth* ft (d)	Volume ft^3 (V)	Trial no.	Bottom diameter (DIA)	Depth* ft (d)	Volume ft^3 (V)
___	_____	_____	____	____	___	_____	_____	_____
___	_____	_____	____	____	___	_____	_____	_____
___	_____	_____	____	____	___	_____	_____	_____
___	_____	_____	____	____	___	_____	_____	_____

* Depth must be adjusted in Step 17.

Depth adjustment

17. Depth adjustment

Depth, ft (d) _____ _____

Add depth of precipitation less evaporation ___+ _____
(For the storage period)

Add depth of 25-year, 24-hour storm _____+ _____

Add for freeboard (1.0 foot minimum) + _____ _____

Final depth _____ _____

Worksheet 10A-3—Anaerobic lagoon design

Decisionmaker:	Date:

Site:

Animal units

1. Animal type _____ _____ _____

2. Animal weight, lbs (W) _____ _____ _____

3. Number of animals (N) _____ _____ _____

4. Animal units, AU = $\dfrac{W \times N}{1000}$ = _____ _____ _____

Manure volume

5. Daily volume of daily manure production per AU, ft^3/AU/day (DVM)= _____ _____ _____

6. Treatment period, days (D) = ------------------- _____

7. Total volume of manure production for animal type for treatment period, ft^3 VMD = AU x DVM x D = _____ _____ _____

8. Total manure production for treatment period, ft^3 (TVM) ------------

Wastewater volume

9. Daily wastewater volume per AU, ft^3/AU/day (DWW) = _____ _____ _____

10. Total wastewater volume for animal description for treatment period, ft^3 WWD = DWW x AU x D = _____ _____ _____

11. Total wastewater volume for treatment period, ft^3 (TWW) ------------------- _____

Clean water volume

12. Clean water added during treatment period, ft^3 (CW) -- _____

Waste volume

13. Waste volume for treatment period, ft^3 WV = TVM + TWW + CW = _____ + _____ + _____ = _____

Manure total solids

14. Daily manure total solids production, lbs/AU/day (MTS) = _____ _____ _____

15. Daily manure total solids production for animal type, lbs/day MTSD = MTS x AU = _____ _____ _____

16. Total manure total solids production, lbs/day (TMTS) = _____

Manure volatile solids

17. Daily manure volatile solids production per AU, lbs/AU/day (MVS) = ------------------- _____ _____ _____

18. Daily manure volatile solids production for animal type per day, lbs/day MVSD = AU x MVS = _____ _____ _____

19. Total manure volatile solids production, lbs/day (TMVS) --- _____

Wastewater volatile solids

20. Daily wastewater volatile solids production, lbs/1000 gal (DWVS) ------------------- = _____ _____ _____

21. Total wastewater volatile solids production for animal type, lbs/day

WVSD = $\dfrac{DWVS \times DWW \times 7.48}{D \times 1{,}000}$ --------------------------- = _____ _____ _____

22. Total wastewater volatile solids production, lbs/day (TWVS) --------------------------------------- = _____

Total volatile solids (manure and wastewater)

23. Total daily volatile solids production, lbs/day TVS = TMVS + TWVS = ------------ _____ + _____ = _____

Minimum treatment volume

24. Selected lagoon VS loading rate, lbs VS/1,000 ft^3 (VSLR) = _____

25. Minimum treatment volume, ft^3

MTV = $\dfrac{TVS \times 1000}{VSLR}$ = $\dfrac{(\quad\quad) \times 1000}{(\quad\quad)}$ = _____

Sludge volume requirement

26. Sludge accumulation ratio, ft^3/lb TS (SAR) = _____

27 Sludge accumulation period, years (T) = _____

28. Sludge volume requirement, ft^3 SV = 365 x TMTS x T x SAR

= 365 x ( )( )( ) = _____

Minimum lagoon volume requirement

29. Minimum lagoon volume requirements, ft^3

(MLVR) = MTV + SV + WV = ------------ _____ + _____ + _____ = _____

Lagoon sizing

30. Sizing by trial and error

$$V = \frac{(4 \times Z^2 \times d^3)}{3} + (Z \times BL \times d^2) + (Z \times BW \times d^2) + (BW \times BL \times d)$$

Side slope ratio, (Z) = _____   V must be equal to or greater than MLVR = _____ ft^3

Trial no.	Bottom width ft (BW)	Bottom length ft (BL)	Depth* ft (d)	Volume ft^3 (V)
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

* Depth must be adjusted in Step 31.

Depth adjustment

31. Depth adjustment

Depth, ft (d) -- _____

Add depth of precipitation less evaporation on lagoon surface _____+   _____
   (for the treatment period)

Add depth of 25-year, 24-hour storm -------------------------- +   _____

Add for freeboard (1.0 foot minimum) --------------------------+   _____

Final depth --- _____

32. Compute total volume using final depth, ft^3 (use equation in step 30) -- _____

Worksheet 10A-4—Aerobic lagoon design

Decisionmaker:	Date:

Site:

Animal units

1. Animal type _____ _____ _____ _____

2. Animal weight, lbs (W) _____ _____ _____

3. Number of animals (N) _____ _____ _____ _____

4. Animal units, AU = $\frac{W \times N}{1000}$ = ____ _____ _____ _____

Manure volume

5. Daily volume of daily manure production
   per AU, ft^3/AU/day (DVM) = _____ _____ _____

6. Treatment period, days (D) = _____ _____

7. Total volume of manure production for
   animal type for treatment period, ft^3
   VMD = AU x DVM x D   = _____ _____ _____

8. Total manure production for treatment period, ft^3 (TVM) _____ _____

Wastewater volume

9. Daily wastewater volume per
   AU, ft^3/AU/day (DWW) = _____ _____ _____

10. Total wastewater volume for animal
    description for treatment period, ft^3
    WWD = DWW x AU x D = _____ _____ _____

11. Total wastewater volume for
    treatment period, ft^3 (TWW) ------------------------------ _____

Clean water volume

12. Clean water added during treatment period, ft^3 (CW) --------------------------------------- _____

Waste volume

13. Waste volume for treatment period, ft^3 WV = TVM + TWW + CW = _____ + _____ +_____ = _____

Manure total solids

14. Daily manure total solids production, lbs/AU/day (MTS) = _____ _____ _____

15. Daily manure total solids production for animal type, lb/day
    MTSD = MTS x AU = _____ _____ _____

16. Total manure total solids production,
    lbs/day (TMTS) = _____

Manure 5-day biochemical oxygen demand

17. Daily manure BOD$_5$ production per AU, lbs/AU/day (MBOD) = ---------------------- _____ _____ _____

18. Daily manure BOD$_5$ production for animal type per day, lbs/day   MBOD = AU x BOD = _____ _____ _____

19. Total manure production, lbs/day (TMBOD) -- _____

Wastewater 5-day biochemical oxygen demand

20. Daily wastewater BOD$_5$ production, lbs/1000 gal (DWBOD) -------------------- = _____ _____ _____

21. Total wastewater BOD$_5$ production for animal type, lbs/day

    WBOD = $\frac{(DWBOD \times TWW \times 7.48)}{D \times 1,000}$ ----------------------------= _____ _____ _____

22. Total wastewater BOD$_5$ production, lbs/day (TWBOD) -- = _____

TOTAL BOD$_5$ (manure and wastewater)

23. Total daily production, lbs/day TBOD = TMBOD + TWBOD = ------------------ _____ + _____ = _____

Minimum treatment surface area

24. Selected lagoon BOD$_5$ loading rate, lbs BOD$_5$/acre (BODLR) = _____

25. Minimum treatment surface area, acres

    MTA = $\frac{TBOD}{BODLR}$ = $\frac{(\quad\quad)}{(\quad\quad)}$ = _____

Sludge volume requirement

26. Sludge accumulation ratio, ft^3/lb TS (SAR)   = _____

27. Sludge accumulation period, years (T)   = _____

28. Sludge volume requirement, ft^3
    SV = 365 x TMTS x T x SAR
    = 365 (____)(____)(____) = _____

Minimum lagoon volume requirement

29. Minimum lagoon volume requirements, ft^3
    MLVR = SV + WV = -- _____ + _____ = _____

Lagoon sizing

30. Sizing by trial and error:

Side slope ratio, (Z) = _____

V must be equal to or greater than MLVR = _____ ft^3

SA must be equal to or greater than MTA = _____ acres

Rectangular lagoon:

d must be less than 5 feet

$$SA = \frac{(BL + 2Zd)(BW + 2Zd)}{43,560}$$

$$V = \left(\frac{4 \times Z^2 \times d^3}{3}\right) + \left(Z \times BL \times d^2\right) + \left(Z \times BW \times d^2\right) + (BW \times BL \times d)$$

Trial no.	Bottom width ft (BW)	Bottom length ft (BL)	Depth* ft (d)	Volume ft^3 (V)	Surface area acres (SA)
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

Depth must be adjusted in Step 31

Depth adjustment

31. Depth adjustment

Depth , ft (d) - . _____

Add depth of precipitation less evaporation on lagoon surface + _____
(for the treatment period)

Add depth of 25-year, 24-hour storm - - - - - - - - - - - - - - - - - - - + _____

Add for freeboard (1.0 foot minimum) - - - - - - - - - - - - - - - - + _____

Final depth - _____

32. Compute total volume using final depth, ft^3
(use equation in step 30) - _____

Worksheet 10A-5—Anaerobic digester design

Decisionmaker:	Date:

Site:

Animal units

1. Animal type _____ _____ _____

2. Animal weight, lbs (W) _____ _____ _____

3. Number of animals (N) _ _ _ _ _ _ _ _ _ _ _ _____ _____ _____

4. Animal units,, $AU = \dfrac{W \times N}{1000}$ = _ _ _ _ _ _____ _____ _____

Manure volume

5. Daily volume of daily manure production
   per AU, ft³/AU/day (DVM)= _____ _____ _____

6. Total volume of daily manure production for animal type, ft³/day

   $MPD = AU \times DVM$ _____ _____ _____

7. Total daily manure production volume, ft³/day (TMP) _ _ _ _ _ _ _ _ _____

Manure total solids

8. Daily manure total solids production, lbs/AU/day (MTS) = _____ _____ _____

9. Daily manure total solids production for animal type, lb/day
   $MTSD = MTS \times AU$ = _____ _____ _____

10. Total manure total solids production, lbs/day (TMTS) = _____

Manure volatile solids

11. Daily manure volatile solids production per AU, lbs/AU/day (MVS) = _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _____ _____ _____

12. Daily manure volatile solids production for animal type per day, lbs/day $MVSD = AU \times MVS$ _____ _____ _____
    =

13. Total manure volatile solids production, lbs/day (TMVS) _ _____

Percent solids

14. Percent solids, % (PS)

$PS = \dfrac{TMTS \times 100}{TMP \times 62.4} = \dfrac{(\qquad) \times 100}{(\qquad) \times 62.4}$ = _____

Digester feed solid concentration

15. Desired digester feed solids concentration, % (DDFSC) =

_____

Daily manure inflow

16. Daily manure inflow, ft³

$DMI = \dfrac{TMTS \times 100}{DDFSC \times 62.4} = \dfrac{(\qquad) \times 100}{(\qquad) \times 62.4}$ = _____

Digester effective volume

17. Digester effective volume, ft³
    $DEV = DMI \times 20 = (\qquad) \times 20$
    = _____

Digester dimensions

18. Digester depth, ft

$H = \left(\dfrac{DEV}{8}\right)^{0.33} = \left[\dfrac{(\qquad)}{8}\right]^{0.33}$ = _____

19. Digest width, ft $WI = 2 \times H = 2 \times (\qquad)$
    = _____

20. Digest length, ft $L = 4 \times H = 4 \times (\qquad)$
    = _____

Estimated energy production

21. Biogas per unit (VS), ft³/lb (BUVS) _____
    =

22. Estimated biogas production ft³/day
    EBP = $BUVS \times TMVS$ = ( ) x ( ) _____
    =

23. Estimated energy production BTU/day
    $EEP = EBP \times 600 = (\qquad) \times (600)$ _____
    =

Worksheet 10A-6—Monthly precipitation minus evaporation

Decisionmaker: _____   Date: _____

Site: _____

Annual FWS Evaporation (*FWS*) = _____ inches

Month	Monthly precipitation MP (inches)	Monthly portion of annual evaporation MPAE (percent)	Monthly evaporation ME (inches)*	Monthly precipitation less evaporation MPLE (inches)
January	_____	_____	_____	_____
February	_____	_____	_____	_____
March	_____	_____	_____	_____
April	_____	_____	_____	_____
May	_____	_____	_____	_____
June	_____	_____	_____	_____
July	_____	_____	_____	_____
August	_____	_____	_____	_____
September	_____	_____	_____	_____
October	_____	_____	_____	_____
November	_____	_____	_____	_____
December	_____	_____	_____	_____

ME = FWS x MPAE

Storage or treatment period, days (D) = _____

months = _____

Critical successive months

Month	Monthly precipitation less evaporation MPLE (inches)	Month	Monthly precipitation less evaporation MPLE (inches)
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
Total	- - - - - - - - - - - - - - - - - - - -		_____

10A–8   (210-vi-AWMFH, rev. 1, July 1996)